IMP. BUREAU ENTOM.
11 OCT 1913

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 5

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
September 27, 1913.

EXAMINED

THE SOUTHERN CORN ROOTWORM, OR BUDWORM.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

DISTRIBUTION.

The parent of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), or, as it is often termed, the budworm, is a yellow or greenish-yellow beetle having 12 black spots on the back, as shown in figure 1, *a*, from which its specific name, meaning "12-spotted," is derived. It is closely allied to the almost equally common striped cucumber beetle (*Diabrotica vittata* Fab.), and also to the parent of the even more destructive western corn rootworm (*Diabrotica longicornis* Say). Throughout the country east of the Rocky Mountains, extending from southern Canada southward to North Carolina, Tennessee, Arkansas, and Oklahoma, these 12-spotted and striped beetles together frequent squashes and pumpkins, often collecting in numbers in the blossoms. The 12-spotted species during late summer and fall also frequents, often in conspicuous numbers, the flowers of the various species of goldenrod (Solidago).

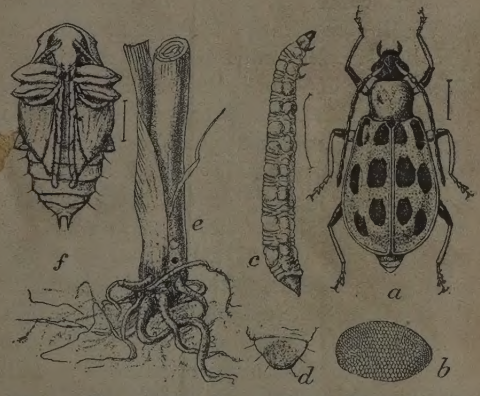

Fig. 1.—The southern corn rootworm (*Diabrotica duodecimpunctata*): *a*, Beetle; *b*, egg; *c*, larva; *d*, anal segment of larva; *e*, work of larva at base of cornstalk; *f*, pupa. All much enlarged, except *e*, reduced. (Reengraved after Riley, except *f*, after Chittenden.)

The larvæ (fig. 1, *c*) do not generally attack growing corn in sufficient numbers to cause any considerable injury, except perhaps

locally, north of the States mentioned in the preceding paragraph, although in 1890 some damage was done in the southern portions of Illinois, Indiana, and Ohio. Southward from the latitude of these States to the Gulf, and extending into Mexico, however, serious ravages are of more or less frequent occurrence. The author reared the beetles from larvæ that were attacking late-planted corn at La Fayette, Ind., during July and early August, 1888, though there was no serious injury to the crop as a whole. A larva was also observed by the author in the act of eating into a stem of young wheat in the field, on October 11, 1890, in the same locality, but the species is not of importance as a wheat insect.

FOOD PLANTS OF THE LARVÆ.

It is probable that the larvæ have attacked corn in the Southern States for at least a century or more. Prof. A. L. Quaintance recorded them as feeding not only on corn but also on the roots of rye, garden beans, and southern chess (*Bromus unioloides*) in Georgia,[1] working serious injury to both corn and beans. The author observed the larvæ attacking young wheat at La Fayette, Ind., October 11, 1890, while Mr. E. O. G. Kelly observed the same thing to occur at Wellington, Kans., October 2, 1907. March 1, 1909, Mr. T. D. Urbahns, at Mercedes, Tex., found larvæ one-half inch in length on the roots of young alfalfa and from these reared adults March 19. April 20, 1911, Mr. George G. Ainslie found larvæ in abundance feeding on the roots of young oats about Jackson, Miss. Adults from these larvæ emerged May 17. The same observer reared adults from larvæ found feeding on the roots of barnyard grass (*Echinochloa crus-galli*) at Hurricane, Tenn., on July 12, 1912, the adults in this case emerging on July 21. The grass upon the roots of which the larvæ were feeding grew up among and between corn that had previously been attacked and killed by the pest.

Dr. F. H. Chittenden[2] states that larvæ or pupæ have been observed at the roots of corn, wheat, rye, millet (*Panicum miliaceum*), southern chess (*Bromus unioloides*), beans, goldenglow (*Rudbeckia* sp.), and sedges of the genera Cyperus and Scirpus. Larvæ have been found and reared by him from about the roots of Jamestown weed (*Datura stramonium*) and pigweed (Amaranthus), and it is not improbable that they feed on these plants.

Prof. E. Dwight Sanderson[3] reported the larvæ working upon the roots of Johnson grass (*Sorghum halepense*) where these roots at the time appeared older than those of the corn. Under date of February 19, 1907, Mr. Dick Hatcher, of Fross, Tex., through Repre-

[1] U. S. Dept. Agr., Bur. Ent., Bul. 26, pp. 38–39, 1900.
[2] U. S. Dept. Agr., Bur. Ent., Circ. 59, p. 4, 1905.
[3] Entomological News, vol. 17, p. 213, June, 1906.

sentative Burleson of that State, informed the writer that the larvæ begin to work on the roots of Johnson grass during the latter part of July. They eat small holes under each joint, and by the latter part of November the roots are dead, and the Johnson grass, as he expressed it, "looks more like rotten sea grass than anything I can compare it to." This correspondent refers to their work on Johnson grass as being more beneficial than otherwise.

FOOD OF THE BEETLES.

The fully developed insect, or beetle (fig. 1, *a*), is a decidedly general feeder, eating readily almost any cultivated plant. A list of its food plants would be more interesting for what it did *not* include and if given in full would be entirely out of place in a publication of this character. Of grain and forage crops it has been observed to feed on corn, wheat, oats, rye, barley, buckwheat (probably), alfalfa, cowpea, soy bean, clover, timothy, milo maize, Kafir, pearl millet, vetch, Johnson grass, and rape.

DEPREDATIONS OF THE LARVÆ IN CORN.

Just when the southern corn rootworm, or budworm, as it is termed in the South, first began to attack corn is involved in obscurity. The writer several years ago[1] called attention to the fact that it was probably this insect to which a Mr. Charles Yancey,[2] of Buckingham, Va., referred when he described "a little white worm with copper-colored head" which, perforating the stalks of young corn "just below the surface of the ground," destroyed the growth. The budworm has certainly been accused of attacking corn in Virginia and other Southern Atlantic Coast States since long before the recollection of the oldest inhabitants. Quaintance[3] found excellent ground for believing that the pest was injurious in the cornfields of Georgia "many years before we find any reference to it in the literature of economic entomology." The first exact observations on the ravages of the larvæ (fig. 1, *c*) in growing corn, the identity of the pest being known at the time the observations were made, were by the writer and published shortly afterwards,[4] as follows:

> While in the South during the spring of 1886 we frequently heard of fields of young corn being seriously injured during some seasons by a small white worm which attacked the roots, usually during April. * * *
>
> On April 12 of the present year [1887] we were enabled to solve the problem by finding considerable numbers of these larvæ in the field of corn in Tensas Parish, La., where they were working considerable mischief by killing the young

[1] U. S. Dept. Agr., Insect Life, vol. 4, p. 264, 1892.
[2] American Farmer, vol. 10, p. 3, 1828.
[3] Loc. cit., p. 36.
[4] Report of the Commissioner of Agriculture for 1887, p. 148, 1888.

plants. As observed by us, their mode of attack differed from that of their northern congener in that they did not appear to attack the fibrous roots or bury themselves in longitudinal channels excavated in the larger roots. On the contrary, they burrowed directly into the plants at or near the upper whorl of roots, which almost invariably resulted in the death of the plant. These larvæ were much more active than those of *longicornis*, and on being disturbed would make their way out of their burrows and attempt to escape by crawling slowly into crevices in the soil, or if it were finely pulverized they would work their way down into it out of sight. Often several individuals, varying greatly in size, would be found about a single plant. On the 20th of same month, in another field, we found the larvæ much more numerous and the crop injured fully 75 per cent. Plants here, 6 to 8 inches high, were withering up and discoloring. Both of these fields had produced cotton the preceding year.

April 27, 1888, serious attacks to young growing corn were observed on Perkins's plantation, near Somerset Landing, Tensas Parish, La., and on May 12 similar depredations were noted in the vicinity of Madison, Ark. Still later the author found the larvæ attacking late-planted corn at La Fayette, Ind., July 12, and on July 14 of the same year 595 of these larvæ were collected and placed in rearing cages, adults from which appeared August 2 and 3. In all of the localities just given, except the last, the ravages were on corn growing in the low damp lands. Throughout the South and even farther north the soil of the lowlands and depressions in fields is of a darker color than that of more elevated areas, hence the statement of farmers and planters that the pest is more destructive on the "black lands." Prof. H. Garman [1] stated that to his personal knowledge corn had been injured during the years 1889 and 1890 in Virginia, Alabama, Mississippi, Louisiana, Arkansas, Kentucky, Illinois, and Ohio.

LOSSES CAUSED BY THE LARVÆ.

As showing the magnitude of the losses caused by this insect, especially throughout the South, illustrations have been selected from notes and correspondence of the bureau. During May, 1906, the writer found that one-fourth to one-third of the young corn growing on the farm of the State Hospital for the Insane, at Columbia, S. C., was being destroyed by these pests. The damage was being done more especially on the low parts of the fields with black or gray soils. Under date of July 15, 1907, Mr. R. F. Haynes, of Cheoah, N. C., stated that the corn crop had been ruined in many places during the spring by a worm that burrowed into the plant just above the base of the roots. Under date of March 20, 1908, Mr. D. P. High, of Whiteville, N. C., stated that farmers in his neighborhood had difficulty in getting a stand of corn on their bottom lands by reason of the attack of these worms. In his opinion it was becoming the greatest cornfield pest, especially in cold, wet

[1] Psyche, vol. 6, p. 30, 1891.

springs, like the one of that year. A similar complaint was received, April 10 of the same year, from Mr. J. L. Hughes, of Chatawa, Miss., who stated that he had replanted his corn three times and the worms were still destroying his crop, although the stalks of corn were 6 inches to a foot in height. Under date of May 24, 1909, Mr. Sidney Johnson, Boydton, Va., sent specimens of the larvæ, with complaints of serious ravages in his neighborhood. March 21, 1910, Mr. Milton Mountjoy, Shacklett, Va., stated that frequently the corn in his neighborhood was ruined over great areas by this pest. Under date of July 30, 1910, Mr. C. L. Foster, of Dalton, Ga., complained of great damage to the corn crop of his section by this pest, and forwarded specimens. In some instances the corn had been replanted three times and still was so badly injured that there was little prospect of a crop. Mr. J. O. Taylor, writing under date of August 17, 1910, from Bastrop, La., stated that early planted corn during that season had been seriously damaged and in many cases destroyed by this rootworm or budworm, which he clearly describes, as well as its method of attack. July 15, 1912, Mrs. A. E. Ballah, of Philippi, W. Va., complained that her corn had been ruined that year by this pest. Writing under date of February 1, 1912, from Brandon, Ky., Mr. Robert B. Parker, statistical agent, stated that corn was damaged 50 per cent in his part of the country by these worms. In some fields they had destroyed as high as 75 per cent of the crop. May 27, 1912, Mr. George G. Ainslie found a portion of a cornfield near Hurricane, Tenn., that had been damaged fully 95 per cent by these larvæ. Under date of December 4, 1912, Mr. G. M. Goforth, county demonstrator, writing from Lenoir, N. C., stated that this worm caused a loss of thousands of dollars every year in his (Caldwell) county.

HABITS OF THE LARVÆ.

The actions of the very young larvæ are in a sense forecasted by the observations made by Quaintance on the method of oviposition. No one else appears to have observed the method of oviposition in the open fields, but Quaintance has found that the stylus-like ovipositor of the female is pushed down into the soil to a depth of from one-eighth to one-fourth of an inch and held there until the egg is forced down the extensible oviduct. This requires usually but a few seconds, and after moving a short distance the beetle may deposit another egg in the same manner.[1] Quaintance further states that larvæ, placed on the roots of corn at one end of a root cage, after the destruction of this corn made their way through the soil to a

[1] Mr. R. A. Vickery, in North Carolina, found that eggs were deposited in the soil by females in confinement without reference to the corn plants growing therein.

plant 10 inches distant. He also observed that larvæ may descend from 8 to 10 inches below the surface of the soil in search of food.

These observations are substantiated by Mr. George G. Ainslie, who studied the habits of the larvæ in the field at Hurricane, Tenn., during May, 1912. In this case, upon digging up the injured corn plants he found that the roots and stem below the ground were grooved, furrowed, and perforated. In many instances there was a distinct perforation into the base of the plant which cut off the crown, thus destroying the central leaves. The larvæ were found either in the partly decayed kernel or along the underground stem in the earth. Only occasionally were the larvæ found with their heads in these holes in the stem. Mr. Ainslie experienced difficulty in finding these larvæ, it being necessary to dig over the earth thoroughly for a considerable distance around each plant, some of the larvæ being found 4 inches from the injured plant and at a depth of 3 or 4 inches. The author also had observed this habit in the young larvæ in previous years, and there is always difficulty in reconciling the number of larvæ one can obtain in badly infested fields with the damage clearly to be charged to them. In many cases the hole made in the plant is not clean-cut, as shown in figure 1, *e*, but has somewhat the appearance of having been simply bruised. This is probably the work of the young larvæ, while the clean-cut hole is the work of those individuals that are larger and more fully developed.

The larvæ of the species under consideration, aside from the work while very young, as described by Mr. Ainslie, eat directly through the outer walls of the base of the plant into the heart of the plant, usually just above the base of the roots, as shown in figure 1, *e*. The term "rootworm" is somewhat of a misnomer, because these larvæ are not usually found in the roots, and as a rule do not feed within them, as is the case with the allied western corn rootworm (*Diabrotica longicornis*).

OVIPOSITION.

The females, which have passed the winter in the adult stage, commence egg laying soon after the first warm weather of spring. The statement of Quaintance that the eggs are usually all deposited within the space of two or three days, while perhaps true as a rule, is not entirely borne out by the observations of others. For instance, Mr. R. A. Vickery at Brownsville, Tex., found that one female deposited 102 eggs during January 18, 19, and 20; another female deposited 22 eggs, 9 on January 19 and 13 on January 28. There does, however, appear to be a tendency on the part of the individual female to complete oviposition within a few days; and this feature in the life history is of considerable economic importance, as it shows that the egg-laying season for the individual in spring is not long drawn

out and that therefore remedial measures will be more effective than they would be otherwise. It has been generally observed, however, as between different females, that some contain eggs much less advanced than others, so that while the time required for the oviposition of a single individual may be very short, some individuals may have finished the process before others have begun. Even under such circumstances the egg-laying period can not be said to be exceptionally protracted.

SEASONAL HISTORY.

While it is possible that the insect may occasionally pass the winter as larva or pupa these instances have been observed too rarely to be considered otherwise than abnormal. Throughout the entire country, from Brownsville, Tex., northward, the insect normally passes the cooler months in the adult stage.

In southern Florida and southern Texas, where the insect remains active throughout the winter, the generations are but indistinctly defined. Northward, however, the species has a definite period of hibernation.

Mr. Vickery has observed the sexes pairing in North Carolina in November, and the author observed this at La Fayette, Ind., September 18, 1888, while Mr. Kelly made a similar observation at Manhattan, Kans. Mr. T. D. Urbahns found larvæ about half an inch in length in the roots of alfalfa at Mercedes, Tex., November 1, 1909, from which two adults developed November 19. Mr. Vickery has observed the males to fight each other most strenuously.

From the foregoing it would seem that pairing may sometimes take place during the late fall prior to the spring oviposition. Certain it is that many of the females are filled with fully developed eggs in very early spring, and, as will be shown, they have been frequently swept from wheat and oats, where they were observed to be feeding, before corn has even been planted.

This early appearance and feeding of the adults has been observed by Mr. Vickery at Winston-Salem, N. C., March 23, on rye, and at Statesville, N. C., March 29, on wheat; by Mr. Urbahns at Santa Maria, Tex., March 6, on oats; by Mr. George G. Ainslie at Nashville, Tenn., January 15, on wheat; and by Mr. C. N. Ainslie at Mesilla Park, N. Mex., April 1, on wheat. Adults were also observed by Mr. Urbahns at Mercedes, Tex., February 18, damaging young alfalfa by feeding on the leaves. At Lanes, Ga., March 3, and at Troy and Montgomery, Ala., March 5, they were observed by Mr. Vickery feeding on oats. Mr. George G. Ainslie observed them at Huntsville, Ala., April 14, feeding on oats; at Franklin, Tenn., February 15 to 18, feeding on wheat; and at Clemson College, S. C., February 20, feeding on oats. Quaintance reported that adults were in evi-

dence at Experiment, Ga., March 12, and that they had become abundant on alfalfa by March 28.[1]

While all of these data may at first seem of little consequence, they bear directly, as will appear later, on what now seems to be the planter's only hope of eliminating the ravages of the pest in his cornfields. It is fair to suppose that these females deposit eggs in the fields as soon as there is food for the larvæ, and it is the larvæ from these eggs that become so destructive in the fields of young corn, especially in the South. The reason they are not equally injurious in the North may perhaps be that by the time oviposition begins in spring and the larvæ have hatched corn has become too advanced in growth to enable these young larvæ to penetrate the stem at the usual point of attack.

Mr. Vickery, who followed the species through the season at Salisbury, N. C., in 1909, settled the question of the number of generations that occur annually at that point, finding that there are two. All of the observations of the author and those of several of the men working under his direction have shown that this is generally true throughout the country where the adult hibernates, but may not apply in the far South, where hibernation does not take place.

Prof. Quaintance, at Experiment, in central Georgia, noted the first appearance of the larvæ attacking corn on May 2. The first pupa was found May 8, and the first adult, evidently of the new generation, May 12.

Mr. C. L. Foster wrote as follows from Dalton, in northern Georgia, on July 30, 1910:

> I am mailing you a sample of worm that is causing great damage to the corn crop of our country. When the corn plant is small these worms bore into the center of the stalk underneath the soil and kill the plant by destroying the "bud." When the plants are larger they bore into some of the larger roots, but more generally into the stalks among the roots, which does not kill the plant outright, but injures it so that it rarely produces corn to amount to anything. The plat where these were found has been planted three times this season, and there are very few stalks now on the plat but what have been injured by the worms. The worms were not so plentiful on July 23 as they were on July 6, when the samples first sent you were collected.

From the foregoing letter it would appear that the second generation of larvæ were at work in late June and July in northern Georgia.

Mr. George G. Ainslie studied the larvæ, at that time 3 to 6 millimeters in length, at Hurricane, Tenn., May 27 to 30, 1912. They must have been full grown by the latter date, as none could be found in the fields June 5, and a recently emerged adult was taken on June 14.

The author observed full-grown larvæ attacking late-planted corn at La Fayette, Ind., July 12, 1888, and in such enormous numbers

[1] Loc. cit.

as to enable him, two days later, to collect nearly 600 for experimentation. It was simply impossible that these could belong to the first generation, as he had frequently observed adults feeding on wheat in the fields in April and early May. One beetle was observed eating out the opening buds of a cherry tree, April 17, 1888. Besides, adults were secured in early August from these larvæ found attacking corn in July. Other adults were observed in the same locality feeding on volunteer oats, December 14, 1888. Clearly there are two generations in the latitude of northern Indiana.

Prof. Quaintance,[1] in central Georgia, found that in one case the period from egg to adult extended from March 14 to May 21, a total of 68 days. In another case this period extended only from April 25 to June 5, or 41 days. Mr. Kelly, at Wellington, Kans., found that the period from egg to adult was 40 to 45 days, while Mr. Vickery, at Salisbury, in western North Carolina, found that this period extended from August 27 or 29 to October 24, or about 58 days.

From all available information it appears that the egg period varies greatly and may require from 7 to 24 days, the larval period from 15 to 35 days, and that of the pupa from 7 to 13 days.

NATURAL ENEMIES.

The Biological Survey has found *Diabrotica 12-punctata* in stomachs of the following 24 species of birds: Bobwhite, *Colinus virginianus* (found in 15 stomachs, one of which contained 12); scaled quail, *Callipepla squamata;* California quail, *Lophortyx californicus;* prairie chicken, *Tympanuchus americanus;* wild turkey, *Meleagris gallopavo;* yellow-bellied sapsucker, *Sphyrapicus varius;* red-headed woodpecker, *Melanerpes erythrocephalus;* nighthawk, *Chordeiles virginianus;* scissor-tailed flycatcher, *Muscivora forficata;* kingbird, *Tyrannus tyrannus;* phœbe, *Sayornis phœbe;* wood pewee, *Myiochanes virens;* western flycatcher, *Empidonax difficilis;* Acadian flycatcher, *Empidonax virescens;* Traill's flycatcher, *Empidonax trailli;* least flycatcher, *Empidonax minimus;* red-winged blackbird, *Agelaius phœniceus;* meadowlark, *Sturnella magna;* Bullock's oriole, *Icterus bullocki;* cardinal, *Cardinalis cardinalis;* rose-breasted grosbeak, *Zamelodia ludoviciana;* cliff swallow, *Petrochelidon lunifrons;* white-eyed vireo, *Vireo griseus;* robin, *Planesticus migratorius.*

The most efficient of the insect enemies of this pest is the fly *Celatoria diabroticæ* Shim. (fig. 2), the maggot of which develops within the body of the adult insect, killing its host. This parasite is not sufficiently abundant, however, to exert much influence in reducing the numbers of the insect.

[1] Loc. cit.

As far back in the past as 1888 the author found larvæ of a click-beetle, *Dasterius elegans* Fab., a close relative of the wireworms, under circumstances that led him to suspect that they were feeding on the budworm. Since that time, also, they have been taken in association with the larvæ of this species and, though never observed in the act, it is not at all unlikely that they do feed upon and destroy the budworm. Mr. Ainslie also encountered them associated with the budworm in his investigations of the latter at Hurricane, Tenn.

REMEDIAL AND PREVENTIVE MEASURES.

After having made its way into the crown of the young corn plant there is no remedy for the work of the pest. The shoot is ruined past all recovery, and the plant will only throw up worthless "suckers," which produce no ears and scant fodder. Fertility of the soil, or the lack of this, does not appear to have any influence on the amount of damage produced.

FIG. 2.—*Celatoria diabroticæ*, a fly parasite of the southern corn rootworm beetle. Much enlarged. (From Chittenden.)

Garman[1] states that of the seriously ravaged fields of corn examined by him one had been grown to tobacco and another to oats the previous year, while a third had been devoted to corn. The ravaged fields observed in Louisiana and Arkansas by the author had all been devoted to cotton the previous year. It would appear, therefore, that crop rotation has little if any effect in protecting fields of corn from the attack of the larvæ.

In the light of all the information at this time available it would seem that the farmer's only hope of relief from the ravages of this pest in the cornfields lies in so timing his planting in spring as not to subject his crop to severe attack. Quaintance, in central Georgia, secured eggs in March and April, 1900; Urbahns found young larvæ at Mercedes, Tex., March 1, 1909; George G. Ainslie observed larvæ attacking oats at Jackson, Miss., April 20, 1911. The author saw them damaging corn at Somerset Landing, La., April 12, 1887, and April 27, 1888; at Madison, Ark., May 12, 1888, and at Columbia, S. C., on May 4, 1906. At the last point the ravages of the larvæ were equally as serious as had been observed years before at Somerset Landing, La., and Madison, Ark., but at Columbia the writer was informed that corn planted after the middle of May escaped injury from the pest. Nearly all of the complaints of injuries from this budworm coming to us from the South refer to damage to the crop early in the season, March or April, although to the northward early May is

[1] Psyche, vol. 9, p. 45, 1891.

included. It would seem, therefore, that there might be a possibility of preventing much of the loss to corn growers in that section of the country by planting corn at a date that would bring the young plants above ground at a time after most of the eggs had been deposited, and not so late as to invite attack from the second generation, which is evidently abroad in the fields in late June and early July in northern Georgia and in July in northern Indiana.

Unfortunately heretofore the bureau has had neither the funds nor the men to carry out an extended investigation of this insect throughout its range of destruction. Now, with field laboratories at Columbia, S. C.; Nashville, Tenn.; Greenwood, Miss.; Brownsville, Tex.; and a temporary field station at Lakeland, Fla.—all equipped for this sort of work and in the hands of experienced men—we hope, with the cooperation of farmers and planters, to learn definitely whether it is not possible through practical measures to prevent the greater part of these ravages, and save or greatly reduce the losses caused by the budworm.

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 5 cents per copy

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1913